Needs for Speed - Categorizing commuter types in the context of smart mobility systems

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NEED FOR SPEED – CATEGORIZING COMMUTER TYPES IN THE CONTEXT OF SMART MOBILITY SYSTEMS

Research Paper

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Abstract

A large proportion of traffic congestion can be attributed to commuters and their travelling behavior. While smart mobility systems (SMSs) intend to address related challenges by actively changing commuters’ behavior, many SMSs lack commuters’ meaningful engagement. Research and practice have started examining engagement factors that increase meaningful engagement with SMSs. The existing approaches, however, often neglect individual commuting-related needs and personal traits – two crucial facets to sustain these systems’ long-term engagement. This paper identifies relevant traffic-related needs and personal traits suitable to improve meaningful engagement. We developed a theoretically sound instrument to categorize commuters in the context of smart mobility and derive first clusters from a pilot study. In the process, we synthesize existing commuter categorizations from psychology and traffic research. This synthesis centers around individual commuting-related needs, personal traits, and objective commuting characteristics. The instrument and pilot study represent a first step toward designing sustainable SMSs with meaningful engagement.

Keywords: Smart mobility, commuter, engagement, questionnaire, cluster analysis.
1 Introduction

Urban development toward smart cities requires the digitalization of the different city domains such as administration, communication, e-government, and traffic (Benevolo et al., 2016; Giffinger et al., 2007). Implemented in these domains, information systems (IS) support both existing structures and processes, e.g., administrative procedures or traffic management (Hofmann et al., 2012; Loukis et al., 2019; Skiftenes Flak et al., 2009; Söderström & Melin, 2019). While the different domains of smart cities usually require specialized IS, the currently developed systems often suffer from a common problem: a lack of citizens’ sustainable engagement (Ebner et al., 2019). However, to be successful, several of the most promising approaches to urban digitalization depend on active and sustained citizens’ engagement (Lindgren et al., 2019). Therefore, in this paper, we employ the concept of meaningful engagement (Armstrong & Manion, 2015; Busseri et al., 2006; Liu et al., 2017), which refers to a dyadic understanding of use comprised of enjoyable experiences fostering use continuance, and instrumental experiences stimulating long-term outcome-oriented use. In our case, meaningful engagement refers to use that supports the achievement of the smart mobility objectives implemented in the smart city.

Researchers and practitioners in the field of e-government, a domain in which engagement with the employed IS is highly relevant, have started examining engagement factors in order to increase meaningful engagement with smart city IS (Hofmann et al., 2012; Liu et al., 2017; Ronzhyn et al.; Scholl et al., 2019). More precisely, alongside e-government, the area of mobility is the most likely to require meaningful engagement because it could help to make cities more sustainable by achieving climate targets (Yigitcanlar et al., 2019). Individuals who travel (e.g., commuters, tourists, or truck drivers) are characteristic of mobility in cities (Anagnostopoulou et al., 2018; Benevolo et al., 2016; Carter et al., 2020; Gil-Garcia et al., 2020). Among those, especially commuters contribute largely to traffic congestion in conurbations and, thus, represent a major lever for reducing such congestion (Anagnostopoulou et al., 2018; Ebner et al., 2019). This study aims to understand the conditions under which users meaningfully engage with a smart mobility system (SMS). To that end, it is necessary to know the needs, personal traits and objective characteristics of commuters, and their behaviors that should be changed to support meaningful engagement with SMSs (Ebner et al., 2019; Liu et al., 2017; Oinas-Kukkonen & Harjumaa, 2008).

Several SMSs are designed to steer single traffic participants using individualized recommendations instead of guiding all traffic participants simultaneously (e.g. using traffic light systems). For this reason, knowledge about individual commuters’ profiles becomes more relevant than before (Benevolo et al., 2016; Fukuda et al., 2016; Oinas-Kukkonen & Harjumaa, 2008). However, since changing people’s traffic-related behavior significantly impacts daily routines, the commuters’ meaningful engagement belongs to the most troublesome challenges encountered to date in the context of smart cities (Anagnostopoulou et al., 2018; Benevolo et al., 2016). Existing approaches often neglect individual commuting-related needs and commuters’ satisfaction, i.e., two crucial facets in sustaining commuters’ long-term engagement with SMS (Anagnostopoulou et al., 2018; Liu et al., 2017; Oinas-Kukkonen & Harjumaa, 2008). If commuters do not perceive their needs as satisfied, they will not be motivated to adapt their behavior according to an SMS’s recommendations.

In summary, to adapt an SMS requires a solid understanding of different (arche)types of commuters (Stone & Schneider, 2016). The existing literature offers various categorizations that classify commuters according to different characteristics and attributes (e.g., environmental interest, Anable, 2005, means of transport, Gottholmseder et al., 2009, or personality and lifestyle, Redmond & Mokhtarian, 2001). However, these categorizations are usually highly specific to a region or transport and vehicle type, or are politically driven, thus lacking scientific grounding, especially when it comes to commuters’ requirements and needs (eurostat, 2016). Moreover, the categorizations do not allow us to draw conclusions on the commuters’ behavior or engagement. Finally, it often remains unclear, which specific underlying factors determined the different categorizations. Considering these challenges to an SMS and existing commuter categorizations, we came up with the following research questions:

RQ1: What needs, personal traits, and objective characteristics of commuters have to be considered to foster meaningful engagement with an SMS?
RQ2: How can commuters’ different needs, personal traits, and objective characteristics be clustered into different commuter types?

To address these research questions, we developed a theoretically sound instrument (a comprehensive questionnaire) for categorizing commuters in the context of an SMS. Based on a literature study, we particularly synthesized existing commuter categorizations from traffic research regarding individual commuter-related needs and personal traits. Further, we integrated the commuters’ willingness and related antecedents to adjust their commuting behavior. We also present, based on a (1) pretest with a convenience sample (n=23), the results of our comprehensive (2) pilot study (n=815) and demonstrate how the data collected with the questionnaire can be used to derive clusters of commuters that are useful in an SMS. The instrument and results represent a first step toward designing a sustainable SMS that fosters meaningful engagement of the commuters (Gregor & Jones, 2007).

2 Theoretical background

In order to answer our research questions, we sought to identify mechanisms that could help to routinize SMS use. Beyond that we wanted to find out which categories of commuters already exist in the literature, how widespread they are, and which criteria are used for categorization. To that end, we performed a systematic literature review according to Webster and Watson (2002). We performed the literature search in the databases ACM Digital Library, the AIS Electronic Library, EBSCO Host, ScienceDirect, Scopus, and Web of Science. In order to fully cover the scientific discourses on an SMS, SMS/smart city engagement, and commuter types, we also specifically searched the AIS Senior Scholar Basket of journals and publications from transport sciences. We searched with the keywords commute OR commuting OR commuter and types, classification, segmentation, categorization, adaptation, needs, and behavior OR behavioral change. We checked more than 450 results for relevance based on abstracts. Additionally, we carried out a backward search to ensure that we had not overlooked relevant work in other journals. This process resulted in us finding some relevant articles that included factors for categorizing commuters, on which we performed an in-depth analysis to categorize commuters. With the help of this analysis we were able to identify correlations between smart mobility, different commuter types, and meaningful engagement, which in our opinion, are essential for the development of a questionnaire that would in the long term assist in developing a successful SMS.

2.1 Smart mobility

Smart mobility is one of the six domains of a smart city (Giffinger et al., 2007). By intelligently using information and communication technologies (Battarra et al., 2016; Gagliardi et al., 2017), an SMS contributes to energy-efficient, low-emission, safe, comfortable, and cost-effective mobility (Benevolo et al., 2016; Fukuda et al., 2016). To address these traffic-related targets, many SMSs intend to change commuters’ behavior. However, the sustainable engagement they need of users is frequently lacking (Anagnostopoulou et al., 2018; Ebner et al., 2019; Gross-Fengels & Fromhold-Eisebith, 2018). Sustainability of use has been investigated for various smart mobility domains, including urban information and service platforms (Anastasi et al., 2013), platforms for route optimization and ticket booking (Tripathy et al., 2018), prevention of traffic congestion with data analytics (Çolak et al., 2015), and intelligent transport systems (Mangiaracina et al., 2017). Table 1 provides an overview of the various designs and possible deployment scenarios discussed in the scientific community and tested in pilot projects.

<table>
<thead>
<tr>
<th>Project (Country)</th>
<th>Description</th>
<th>Conclusion</th>
<th>Reference(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MatkaHupi (Finland)</td>
<td>Researchers attempted to encourage a navigation app’s users to make more sustainable mobility decisions through challenges.</td>
<td>Users want to personalize the challenges (e.g. who travels a route more sustainably).</td>
<td>Gabrielli et al., 2014, Jylhä et al., 2013</td>
</tr>
</tbody>
</table>
Table 1. Overview of smart mobility projects (extended from Anagnostopoulou et al., 2018)

<table>
<thead>
<tr>
<th>Project</th>
<th>Description</th>
<th>Outcome</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPET (Italy)</td>
<td>Using a smartphone app, researchers attempted to reduce app users’ car use through persuasive messages.</td>
<td>Users weigh travel duration / costs / CO2 emissions.</td>
<td>Meloni et al., 2014, Meloni &amp; Di Teulada, 2015</td>
</tr>
<tr>
<td>PerCues (Austria)</td>
<td>Researchers made an attempt to motivate smartphone app users to use public transport instead of their car.</td>
<td>The timing of system use is critical to its success.</td>
<td>Reitberger et al., 2007</td>
</tr>
<tr>
<td>Peacox (Austria)</td>
<td>Researchers used personalized, multi-modal route suggestions from a smartphone app to encourage users to make more sustainable mobility decisions.</td>
<td>Positive change in user attitudes. No measurable change in behavior.</td>
<td>Bothos et al., 2014, Busch et al., 2013, Schrammel et al., 2015</td>
</tr>
<tr>
<td>QT (USA)</td>
<td>Researchers examined whether sustainable route suggestions could be automated via a cloud application instead of a personal consultant.</td>
<td>More interaction with the website leads to more sustainable decisions.</td>
<td>Jariyasunant et al., 2015</td>
</tr>
<tr>
<td>Superhub (Italy)</td>
<td>Researchers investigated how the influence of gamification in the context of a smartphone app for route planning affects users’ mobility decisions.</td>
<td>The study proved a positive influence of gamification on the users’ transport decisions.</td>
<td>Alrefaie et al., 2014, Carreras et al., 2012, Forbes et al., 2012; Gabrielli &amp; Maimone, 2013, Wells et al., 2014</td>
</tr>
<tr>
<td>Tripzoom (Netherlands, Sweden, UK)</td>
<td>Researchers investigated how mobility records, incentives, and social networks can be used in the context of behavioral change.</td>
<td>The living lab study proved positive effects with incentives and social computing in a smart city.</td>
<td>Bie et al., 2012, Broll et al., 2012, Holleis et al., 2012</td>
</tr>
<tr>
<td>UbiGreen (USA)</td>
<td>Researchers investigated whether the users' graphical visualization of recorded mobility data has an influence on their transport decisions.</td>
<td>Positive effects on the users' environmental awareness could be proven.</td>
<td>Froehlich et al., 2009</td>
</tr>
<tr>
<td>VR (Italy)</td>
<td>Researchers used a smartphone app to investigate gamification's influence on users’ mobility decisions.</td>
<td>Gamification can lead to more sustainable mobility decisions.</td>
<td>Kazhamiakin et al., 2015; Kazhamiakin et al., 2016</td>
</tr>
<tr>
<td>Streetlife (Germany)</td>
<td>Researchers investigated the influence of gamification on users’ choice of transport mode (bicycle vs. car).</td>
<td>Positive influence of gamification on users’ choice regarding means of transport.</td>
<td>Kelpin et al., 2016</td>
</tr>
</tbody>
</table>

2.2 Commuter types

In the context of an SMS, commuters are a central user group. We therefore propose that an SMS’ adaptation to different commuter types is particularly valuable for the success of an SMS and the associated traffic relief. People in traffic have been categorized according to different criteria, such as environmental interest (Anable, 2005), route characteristics (Gottholmseder et al., 2009), personality and lifestyle (Redmond & Mokhtarian, 2001), route selection (Haselkorn et al., 1989), or attitudes toward car use (Jensen, 1999) (see Table 2 for a more detailed overview of different commuter categorizations).
The characteristics various studies examined are often very dissimilar; however, a basic categorization according to general traffic-related behavior, needs, and personal traits is possible. On the one hand, general traffic-related behavior comprises objectively quantifiable criteria, such as possession of or access to certain means of transport (Collins & Chambers, 2005), the length, duration, and nature of a commute (Gottholmseder et al., 2009), or the frequency of a specific traffic-related behavior (Verplanken et al., 1994). On the other hand, needs and personal traits address subjective traffic-related necessities. They form a situation-dependent subset of individual needs. If an SMS satisfies these needs, users will be more motivated to continue their use and more intensely engage with the SMS (Oinas-Kukkonen & Harjumaa, 2008; Ryan & Deci, 2000). Among the needs identified in the existing literature are the need for autonomy in choosing means of transport and routes (Ziegler et al., 2018), the need for environment-friendly mobility (Anable, 2005), the need to complete work-related tasks (Sheldon et al., 2001), or the need to interact with other people (Ryan & Deci, 2000). These characteristics also feature in qualitative studies by Jensen (1999) and Ziegler et al. (2018), which contribute important findings.

Beyond these aspects, most of the evaluated sources to some extent include contextual characteristics (e.g. biking or carsharing behavior), which include all study-specific characteristics that form the basis of the particular research project, and have not already been covered by the factors described above. To sum up, as can also be seen in Table 2, different approaches to categorize commuters have covered different aspects. However, none of these earlier studies offers a comprehensive approach covering a broad and holistic range of needs and traffic-related behaviors that are required to adapt an SMS to individual commuters, and thus to sustain long-term engagement with these systems.

<table>
<thead>
<tr>
<th>Source</th>
<th>Investigated characteristics</th>
<th>Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anable, 2005</td>
<td>Moral norms, environmental interest, ideology, education, self-efficacy, behavioral norms, habits.</td>
<td>Classification of mobility types, willingness to adapt (means of transport).</td>
</tr>
<tr>
<td>Gottholmseder et al., 2009</td>
<td>Route characteristics (duration, means of transport, reliability, crossing borders), demography.</td>
<td>Perceived stress on the way to work.</td>
</tr>
<tr>
<td>Haselkorn et al., 1989</td>
<td>Route, route selection, reference of traffic information.</td>
<td>Readiness to adapt (distance, time).</td>
</tr>
<tr>
<td>Jensen, 1999</td>
<td>Demographics, opinions, and attitudes toward using a car.</td>
<td>Classification of mobility types (by means of transport, behavior and attitude).</td>
</tr>
<tr>
<td>Khattak et al., 1993</td>
<td>Limitation, characteristics of the alternative route, direction, demographics, personality, situational factors.</td>
<td>Readiness to adapt (distance).</td>
</tr>
<tr>
<td>Redmond &amp; Mokhtarian, 2001</td>
<td>Objective mobility, perceived mobility, relative aspired mobility, personality, lifestyle.</td>
<td>Factors influencing the discrepancy between preferred and actual commuting duration.</td>
</tr>
<tr>
<td>Simma &amp; Axhausen, 2001</td>
<td>Binding (car, public transport), general mobility behavior, sociodemography.</td>
<td>Transport commitment's influence on the means of transport used.</td>
</tr>
<tr>
<td>St-Louis et al., 2014</td>
<td>Journey characteristics, journey time, means of transport preference, journey preference, personal properties.</td>
<td>Factors influencing satisfaction (in relation to choice of transport mode)</td>
</tr>
<tr>
<td>Verplanken et al., 1994</td>
<td>Attitude (regarding car and train use), habit of using the car, decision involvement.</td>
<td>What influences the choice of means of transport (focus on motorists).</td>
</tr>
<tr>
<td>Ziegler et al., 2018</td>
<td>Stimulation, physical well-being, safety, popularity, self-realization, autonomy.</td>
<td>Classification of mobility types</td>
</tr>
</tbody>
</table>

Table 2. Overview of existing categorizations in the mobility sector.
Many of the listed studies remain too generic or vague in their conclusions concerning sustained engagement. The findings either only stress the relevance of long-term engagement without offering a more specific account on how to achieve it (Anable, 2005; Khattak et al., 1993; Ziegler et al., 2018), or are loosely based on traditional technology adoption research. Due to the strong ties technology adoption studies have to organizational contexts, this only very limitedly applicable to urban environments (Gottholmseder et al., 2009; Redmond & Mokhtarian, 2001). Anagnostopoulou et al.’s (2018) comparative meta-study on an SMS offers an exception in positing that an SMS’s adaptation to users’ needs and personal traits is a central element in long-term engagement with these systems. In other smart city domains, such as smart governance, research could also demonstrate system adaptation to users’ needs and personal traits having a positive influence on the frequency of people using e-government systems (Krishnaraju et al., 2016). Blom (2000), Fan and Poole (2006), and Sun (2012) all define adaptation as a process that changes a system’s functionality, user interface, access to information and content, or special features in order to increase the personal fit between system and user.

Summarizing the discussions above, the question of how mobility participants can be motivated to sustainably engage long-term with an SMS has not been answered satisfyingly yet. However, since a few studies (beyond Anagnostopoulou et al., 2018 or Gabrielli et al., 2014) suggest adaptation as a fruitful approach, we follow this line of thought in our work.

2.3 Meaningful engagement

Following authors such as Armstrong and Manion (2015), Busseri et al. (2006), Liu et al. (2017), we argue on the one hand that an SMS should lead both to enjoyable experiences that foster use continuance and to users completing traffic-related tasks. On the other hand, the SMS must stimulate long-term outcome-oriented use, i.e., use that supports relieving traffic by reminding users of the importance of how they use transport. Liu et al. (2017) refer to this dyadic understanding of use as meaningful engagement. Following Liu et al. (2017) meaningful engagement describes use that stresses the dual outcomes of interactions with a gamified information system, i.e., instrumental and experiential outcomes. Since meaningful engagement stresses the relevance of both use continuance and outcome-orientation, we propose that it represents an excellent concept to qualify the sustainability of use in smart mobility contexts. With respect to the experiential dimension of meaningful engagement, past research shows that enjoyable experiences can reflect in states of flow, cognitive absorption, and enjoyment (Li et al., 2013; Penenberg, 2013; Thiebes et al., 2014). Since in meaningful engagement use is experienced as convenient and fun, it is more difficult to give up (Armstrong & Manion, 2015), thus it supports continued use of an SMS (Ebnert et al., 2019). Additionally, an SMS that actively supports users in their task-completion, counteracts states of frustration, thus further contributes to use continuance (Oinas-Kukkonen & Harjumaa, 2008; Schiefelbein et al., 2019).

Further, with meaningful engagement, use is believed to be important to reach individuals’ goals or target behaviors (Agnisarman et al., 2018) since an SMS changes users’ attitudes and behavior by incrementally convincing them of specific (traffic-related) tasks and activities (Schiefelbein et al., 2019). Consequently, users are more prone to follow the recommendations of an SMS and in that way, they contribute to relieving traffic (Ebnert et al., 2019). We agree with other researchers (e.g. Agnisarman et al., 2018 or Liu et al., 2017) that meaningful engagement can be supported by considering the individual commuting profile of an SMS user. We summarize the relationship between an SMS, commuter types and meaningful engagement in our research framework in Figure 1. For meaningful engagement it is necessary, that we know the different commuter types. This knowledge is critical in allowing us to adapt personal recommendations from the SMS to the individual needs and personal traits that assure meaningful engagement. For this purpose, we created a comprehensive questionnaire to determine the different types of commuters, which we will introduce in the remainder of the paper.
2.4 Commuters’ meaningful engagement in the context of smart mobility

We find that various past researchers have investigated mechanisms to support the long-term use of SMS (Benevolo et al., 2016; Maslow, 1943; Oinas-Kukkonen & Harjumaa, 2008). All of these approaches have in common that they intend to increase users’ motivation either by rewarding the use of SMSs, thus triggering extrinsic motivation (e.g. approaches that employ gamification; Deterding et al., 2011; Anschütz et al. 2020), or by specifically addressing personal needs (Fronemann & Peissner, 2014; Reiss, 2004; Ryan & Deci, 2000; Sheldon et al., 2001), thus triggering intrinsic motivation (Oinas-Kukkonen & Harjumaa, 2008). In both cases, the mechanism underlying the sustained use is satisfaction that, in turn, will increase extrinsic and intrinsic motivation (Ryan & Deci, 2000). Intrinsic motivation satisfies psychological needs such as autonomy, competence, and (social) relatedness (Ryan & Deci, 2000), while extrinsic motivation satisfies hedonistic (fun) and rewards needs (Liu et al., 2017). Needs that are specifically related to traffic form a situation-dependent subset of the general needs and include, for example, autonomy in choosing transportation vehicles and routes, and safety (Dietiker et al., 1998; Reiss, 2004; Ryan & Deci, 2000; Sheldon et al., 2001; Ziegler et al., 2018). Table 3 summarizes different needs that we identified as relevant in the literature.

<table>
<thead>
<tr>
<th>Need</th>
<th>Definition (Sheldon et al., 2001)</th>
<th>Context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomy</td>
<td>…to feel that activities are self-chosen and self-endorsed.</td>
<td>Ryan &amp; Deci, 2000 (X) Frömmann &amp; Peissner, 2014 (X) Reiss, 2004 (X) Sheldon et al., 2001 (X) Ziegler et al., 2018 (X)</td>
</tr>
<tr>
<td>Competence</td>
<td>…to feel that one is effective in one’s activities.</td>
<td>X (X) X X X X</td>
</tr>
<tr>
<td>Relatedness</td>
<td>…to feel a sense of closeness with a number of others.</td>
<td>X (X) X X X</td>
</tr>
<tr>
<td>Self-actualization/meaning</td>
<td>…to feel a sense of long-term growth and deeper purpose in life.</td>
<td>(X) (X) X X</td>
</tr>
<tr>
<td>Physical thriving</td>
<td>…to feel that one is in excellent physical condition.</td>
<td>X X X X X</td>
</tr>
<tr>
<td>Pleasure/stimulation</td>
<td>…to experience new sensations and activities.</td>
<td>(X) X X</td>
</tr>
<tr>
<td>Security</td>
<td>…to feel a sense of stability.</td>
<td>X X X</td>
</tr>
<tr>
<td>Popularity/image</td>
<td>…to feel liked, respected, and that one influences others.</td>
<td>X X X</td>
</tr>
</tbody>
</table>

Table 3. Derivation of relevant needs for further analysis
The overview in Table 3 gives valuable hints toward the development of our questionnaire, as it shows that only one paper (Ziegler et al., 2018) addresses traffic-related needs that to a certain extent differ regarding the needs addressed. In contrast, four sources consider general needs. All of them (the earlier four in Table 3) address autonomy, competence, and relatedness.

3 Research method

To derive the relevant factors for our commuter categorization, we developed a questionnaire based on the analyzed literature. We based the procedure of developing the underlying constructs for the questionnaire on MacKenzie et al. (2011). For the construct selection process, the literature search we had carried out before was pivotal. In order to measure these constructs, we compiled relevant indicators and operationalization based on established literature (such as Anable, 2005; Dunlap et al., 2000; Gøtholmseder et al., 2009; Proyer, 2012). For cases in which we could not derive an operationalization from the literature, we developed own items, following Kroesnick (2018).

During the pretest in which people not involved in the design process tested the questionnaire to achieve an optimal result in the later pilot study, we aimed to determine the questions’ comprehensibility and any ambiguities in the answers (MacKenzie et al., 2011). The pretest procedure fundamentally followed Porst’s (2014) suggestions. Consequently, the questionnaire was made available to a convenience sample (n=23) under real conditions, supplemented on the last page with questions on length, design, and comprehensibility. Moreover, the respondents had an opportunity to comment on individual questions or pages of the questionnaire at any time via a comment function. We used the survey software Unipark to record and evaluate important key figures, such as termination rates, pages with long retention times, and the total processing time. The questionnaire pretest for categorizing commuter types comprised a total of 115 items, which measured 141 variables and achieved a utilization rate of 76.66% with an average total processing time of 31.1 minutes. We found a low response rate (< 80%) for 26 items. From the comments, we deduced that the participants had problems with the control element slider in itself (missing initial state, unclear regarding deselectability). Further, the remarkably high non-response to these questions made it clear that many participants were reluctant to perform the comparatively high cognitive work necessary to answer the questions. After a two-step card sorting with 12 researchers not involved in the research project, the pretest’s findings became the basis for the revised categorization instrument that had 102 items overall.

Our pilot study that ran for four weeks in fall 2019 in the setting of our students, who are employed, are 38 years old on average, and who primarily intend further education in using the studies, resulted in a convenience sample (n=815). After comprehensive data cleansing (removal of incomplete or incorrect data records), 630 data records remained. Using this data, we conducted a cluster analysis (Balijepally et al., 2011; Ketchen Jr. & Shook, 1996; Landau et al., 2014). To estimate the number of clusters, we used the hierarchical method with the ward distance measure (Saraçli et al., 2013) and squared Euclidean distance (Sherali & Tuncbilek, 1992). The result was four clusters which were then considered in k-means used to evaluate our data set (Kuncheva & Vetrov, 2006). We discuss the results of the pilot study in more detail in section 5.

4 Categorization instrument

Next, we introduce the details of our developed instrument focusing on the items that the pretest identified as relevant. The complete questionnaire and the corresponding scales are not included in this paper, but we will gladly provide them to interested readers. Figure 2 illustrates the framework for our cluster analysis. It shows the constructs relevant for our questionnaire which we discuss below. The questionnaire is divided into two question blocks of which the first focuses on the objective factors (e.g. general mobility behavior), and the second on the individual needs and personal traits. Due to its self-explanatory structure, demography (e.g. gender, age, household income, educational attainment) will not be discussed in detail below; nevertheless, it is highly relevant for the cluster analysis.
4.1 Objective factors (of personal mobility)

The objective factors by which commuter types can be distinguished include general mobility behavior, existing commuting habits, and the objective characteristics of the commuting route. First, in this paper we define general mobility behavior as ownership or unrestricted access to different transport modes (Simma & Axhausen, 2001), their average use frequency, and a possible change in future use (Anable, 2005). The construct describes the mobility behavior without concrete restrictions regarding a certain context, for example, the route to work (Redmond & Mokhtarian, 2001). Second, existing commuting habits can be defined as a "recurring, everyday phenomenon that is not reconsidered every day and decided upon anew taking into account all its characteristics" (Busch-Geertsema et al., 2016). This includes, on the one hand, how long a commuter has been using the same route to work (Gottholmseder et al., 2009) and, on the other, how sensitively he or she reacts to restrictions on the journey to work (Khattak et al., 1993). And third, the objective characteristics of the commuting route refers to the distance to the workplace (Haselkorn et al., 1989) and the change of transport means within the commuter route (Gottholmseder et al., 2009), among others. We use(d) this objective to categorize commuters in the context of this work. However, the quality of a commuting route encompasses a multitude of different dimensions and can sometimes have a far-reaching effect on commuters’ stress perception (Gottholmseder et al., 2009) or health (Cole-Hunter et al., 2012; Olsson et al., 2013).

4.2 Needs and personal traits

Commuters have distinct needs and personal traits that feature their way to work. Table 4 lists all the constructs we included in our categorization instrument. The needs on the way to work are a situation-specific subset of personal needs (Dietiker et al., 1998). They describe what is important to commuters on their route to work and explain the motives for the concrete design of a commute, such as the need to complete work-related tasks (Fronemann & Peissner, 2014), the need for interaction with other people (Sheldon et al., 2001), or the need to spend time as pleasantly as possible (Reiss, 2004). Based on our literature review, we include autonomy, competence, social involvement, sustainability, enjoyment, and popularity in our categorization instrument (Dunlap et al., 2000; Fronemann & Peissner, 2014; Pruyer, 2012; Reiss, 2004; Ryan & Deci, 2000; Sheldon et al., 2001; Ziegler et al., 2018), since prior research employed these constructs most frequently. Personality can generally be defined as the "totality of all enduring individual characteristics in the experience and behavior of a person" (Asendorpf, 2014).
We constructed a confirmatory factor analysis using SPSS AMOS to check for validity and internal consistency validation and needed to be revised. A surprising finding was that the operationalization of sympathy, which had worked in other studies, did not lead to strong correlations and loadings in our context (Cialdini, 1993). We are still investigating why this was the case, but we assume that the original operationalization measured facets quite broadly, while in a traffic context only certain sympathy facets might work, while others have an opposing effect. For example, a car driver might feel sympathy for other people in traffic jam, but would not necessarily follow their suggestions to take an alternative route, since he might suspect that too many others would do so as well, thus, leading to a new traffic jam on a new route. Consequently, we used the remaining constructs for the cluster analysis. We performed a confirmatory factor analysis using SPSS AMOS to check for validity and internal consistency reliability (Shek & Yu, 2014). According to Straub & Gefen (2004) the convergent validity of our constructs was assessed by the Average Variance Extracted (AVE) and Composite Reliability (CR). The values for AVE were greater than 0.5 for all factors with the exception of Autonomy (0.444). We exceeded CR for all values (greater than 0.7) with one exception (Autonomy with 0.615). According to

![Table 4. Overview of the constructs used in our categorization instrument.](image)

<table>
<thead>
<tr>
<th>Sources</th>
<th>Construct</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bergstad et al., 2011, Russell et al., 1989, Västfjäll et al., 2002</td>
<td>Valence*</td>
<td>The degree of positivity a commuter shows related to his/her daily work route.</td>
</tr>
<tr>
<td></td>
<td>Degree of Activation*</td>
<td>The degree of activity a commuter shows on his/her daily route to work.</td>
</tr>
<tr>
<td></td>
<td>Competence</td>
<td>The need to be capable and effective in one’s own action.</td>
</tr>
<tr>
<td></td>
<td>Social Involvement*</td>
<td>The need to have regular trusting contact and interaction with important others without feeling alone or unloved.</td>
</tr>
<tr>
<td></td>
<td>Sustainability*</td>
<td>The need to live one’s life in harmony with and consideration of the environment.</td>
</tr>
<tr>
<td></td>
<td>Enjoyment</td>
<td>The need to amply experience fun and pleasure, rather than feeling bored and cognitively insufficiently stimulated.</td>
</tr>
<tr>
<td></td>
<td>Popularity</td>
<td>The need to feel liked and respected and to have an impact on others.</td>
</tr>
<tr>
<td>Asendorpf, 2014, Cialdini, 1993, Costa &amp; McCrae, 1992, Dunlap et al., 2000, Kaptein et al., 2012; Proyer, 2012</td>
<td>Reciprocity</td>
<td>The desire to return favors to others with the aim of not being indebted to another person.</td>
</tr>
<tr>
<td></td>
<td>Scarcity*</td>
<td>The susceptibility to wanting more of those things less available to people.</td>
</tr>
<tr>
<td></td>
<td>Authority</td>
<td>The need to comply with persons perceived as superior regarding some specific aspect.</td>
</tr>
<tr>
<td></td>
<td>Commitment</td>
<td>The tendency to consistently meet promises and assertions once they have been made.</td>
</tr>
<tr>
<td></td>
<td>Conformity</td>
<td>The desire to behave in accordance with a specified standard or authority.</td>
</tr>
<tr>
<td></td>
<td>Sympathy</td>
<td>Preference to comply with the requests of those we like rather than those we don’t like.</td>
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</tbody>
</table>

5 Results of the pilot study

Based on revised data from the pilot study, we conducted a comprehensive cluster analysis. This analysis led us to a number of different findings with respect to both the items and the overall applicability of our categorization instrument. First of all, we found that the inverted items did not work well at all in the measurement model validation. Further, 25 items (out of 102) did not work well during instrument validation and needed to be revised. A surprising finding was that the operationalization of sympathy, which had worked in other studies, did not lead to strong correlations and loadings in our context (Cialdini, 1993). We are still investigating why this was the case, but we assume that the original operationalization measured facets quite broadly, while in a traffic context only certain sympathy facets might work, while others have an opposing effect. For example, a car driver might feel sympathy for other people in traffic jam, but would not necessarily follow their suggestions to take an alternative route, since he might suspect that too many others would do so as well, thus, leading to a new traffic jam on a new route. Consequently, we used the remaining constructs for the cluster analysis. We performed a confirmatory factor analysis using SPSS AMOS to check for validity and internal consistency reliability (Shek & Yu, 2014). According to Straub & Gefen (2004) the convergent validity of our constructs was assessed by the Average Variance Extracted (AVE) and Composite Reliability (CR). The values for AVE were greater than 0.5 for all factors with the exception of Autonomy (0.444). We exceeded CR for all values (greater than 0.7) with one exception (Autonomy with 0.615). According to
Hair (2010) we used the Fornell-Larcker criterion to assess discriminant validity: The square root of the average variance extracted for each construct was significantly greater than the correlation between the construct and any other construct and exceeded the satisfying threshold of 0.65 for all constructs. The constructs which contributed best to deriving clusters are marked with an asterisk in Table 4.

With the cluster analysis (using k-means algorithm), we intended to gain insight on the overall applicability of our categorization instrument (Straub & Gefen 2004). In particular, we wanted to see whether our set of cluster variables would allow us to derive meaningful and interpretable clusters. These clusters do not exclusively refer to commuter types that describe traffic, but are focused on the design of meaningful SMSs with persuasive elements, focused on interpretable needs and personal traits. As a result of this clustering, we were able to derive the four different clusters of commuters shown in Table 5.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>Heteronomous loners</td>
<td>Susceptible to time, mostly car drivers, but tend to use the transportation means that saves them the most time.</td>
</tr>
<tr>
<td>Tired routinizers</td>
<td>Susceptible to cost savings, high need for autonomy in travelling, low degree of activity on their way to work, use the same commuting routines every day.</td>
</tr>
<tr>
<td>Green routinizers</td>
<td>Susceptible to sustainability and health-related arguments, high need for autonomy in travelling.</td>
</tr>
<tr>
<td>Self-determined passengers</td>
<td>Susceptible to travel time and social interaction, they want to self-determine their way of travelling as long as it is sustainable and allows for social interaction.</td>
</tr>
</tbody>
</table>

Table 5. Commuter types from the pilot study.

Figure 3 shows the four clusters given in Table 5, including the different characteristics of the cluster variables. It shows, on the one hand, the difference between the more autonomous tired routinizers and the green routinizers to be that the latter emphasize sustainability more strongly. The heteronomous loners, on the other hand, are less interested in social involvement than the self-determined passengers, and are generally satisfied with their regular way to work.

Figure 3. Preliminary clusters from the pilot study.
In a further step, we used different control variables to check the details in which the four clusters additionally differ. We found that heteronomous loners use the possibility of renting a car much more often than the other three groups do (e.g., car rental or car sharing). In contrast, the green routinizers and self-determined passengers most often use public transport to get to work. Interestingly, the tired routinizers most often use their own bicycle to get to work. The findings from the choice of transport mode remain applicable to the route to work. Tired routinizers on average have the shortest distance to cover, whereas self-determined passengers have the longest distance. It is further interesting that the clusters of heteronomous loners and green routinizers are almost balanced in terms of gender, whereas the tired routinizers are predominantly female (57.76%) and the self-determined passengers are predominantly male (55.75%). In terms of the remaining demographic data, all clusters are similar, namely on average between 25 and 44 years of age and with incomes between EUR 1000 and EUR 3500 per month.

With this knowledge of the different commuter types, we can adapt personal recommendations from an SMS to the individual needs and personal traits required for meaningful engagement and an SMS’s long-term use. These findings form an important basis for the SMS’s design. Since in the context of SMSs comparably little information is obtained from users (e.g., due to data protection regulations), it is important that we determine, in terms of meaningful engagement, which variables provide the highest explanatory value for interpretation while, at the same time, keep the amount of information required from the user as small as possible. Hence, we need to ask: What is the most parsimonious number of clustering variables we can use to derive both interpretable and meaningful clusters? By meaningful clusters, we mean that the characteristics provided go beyond traditional commuter information and offer concrete insights on adequate persuasive design elements and principles. For example, for green routinizers it is important, that persuasive elements highlight which sustainability goals have been reached by repeated use of the SMS. This could, for example, be attained by displaying messages on latest CO2 savings by adjusted commuting behaviour, thus contributing to instrumental outcomes (i.e., changing routines). From an experiential outcome perspective, green routinizers, who have a high need for autonomy and are cognitively active during their commute, might be challenged by finding a commute that e.g. produces 5% less CO2 or that offers intermodal options. For heteronomous loners, which tend to use the transportation means that saves them the most time, it is highly relevant, that the persuasive elements praise users that follow the recommendations (that shows the fastest way to the commuting destination) of the SMS. Tired routinizers, which use the same commuting routines every day, can be motivated with gamified task on their daily way to work to use the SMS meaningfully. And for self-determined passengers, persuasive elements in the SMS should be designed with the focus of social interaction with other commuters.

Another, more gamification-oriented example of a prototypical design feature with regard to experiential outcomes in SMS is awarding (Liu et al., 2017). This means that the SMS shall award commuters for special achievements (Anschütz et al., 2020). For example, heteronomous loners may be interested in awards that show that they have covered a distance faster than the last time for a specified amount of times, whereas tired routinizers could receive a badge for having covered a distance particularly cheaply. Since green routinizers pay a lot of attention to sustainability, the achievement here should be designed for the sustainable completion of a route. On contrary, the achievement for the Self-determined passengers can be designed for the common achievement (in a team) of a goal. Having such awards with different levels of difficulty (e.g., times successful concerning a goal) that require continued use may then in turn contribute to instrumental outcomes of sustained use.

6 Conclusion and next steps

This paper aimed to categorize commuter types for meaningful engagement by means of a cluster analysis based on a theoretically sound and validated instrument. We employ general mobility behaviors and needs as well as personal traits relevant for the categorizing. In particular, the needs and personal traits represent central components of the developed categorization, due to their importance for the design of traffic actions. The presented instrument represents a central and necessary first step for develop-
opposing an SMS that explicitly accounts for commuters’ needs. The categorization enabled by our instrument allowed to cluster commuter types, thus fostering the design of features and principles that promote meaningful engagement for long-term use (Gregor & Jones, 2007). Beyond the smart mobility context, the questionnaire we developed offers a theoretically sound starting point for further research projects in other domains of a smart city, that aim to improve the long-term engagement of e-government system users. Beyond that we hold that the questionnaire we developed can be a starting point for researchers in other domains who aim at better understanding long-term use, personalized and persuasive IS design.

Despite these contributions, our research is not free of limitations. In a first step, we had to balance the breadth of the considered factors with the clustering abilities of our instrument and general instrument length. For instance, Anable (2005) focuses primarily on the intentions and behavior in a general traffic context and categorizes the results on the basis of users’ psychological dependence on car use. This paper’s focus, on the contrary, is primarily on the daily journey to work, and the commuter’s willingness to adapt his or her behavior to an SMS’s objectives. Therefore, we used a comparatively narrower level of consideration for the categorization. The decision to consider mainly commuters at first reduces the generalizability, but it also gives very concrete insight into a defined sub-area. Another point of relevance in this context is the length of the resulting survey instrument. With 102 items in all and some longer questions, the questionnaire was too long for some participants. Problems such as fatigue and a decreasing ability to grasp and concentrate during the course of the questionnaire, may have led to systematic distortions of the results (Krosnick, 2018; Porst, 2014). Some of the constructs in our questionnaire, which worked in other contexts (e.g. sympathy), do not work in the specific traffic-related context. These constructs must be adjusted in a revised version of the questionnaire.

Other methods of data acquisition in the field of traffic research, such as recording GPS data or triangulating mobile phone data, support the respondents, but do not provide information relevant to their needs or motivation. Combined methods of GPS data and (interview or online) surveys may lead to a more comprehensive and detailed database, but are very complex to implement and less suitable for larger surveys. The online survey method used in the pilot study is partially controversial. Besides advantages such as low financial and personnel costs and the absence of interviewer effects or effects of social desirability, there is criticism regarding a social decontextualization of the interviewees (Krosnick, 2018). Due to the absence of a social setting, respondents might respond more self-centeredly when they complete the survey than in a survey that takes place in a fixed social environment. This disadvantage can, however, have a positive effect on the quality of the answers in research projects with a pronounced individual focus, for example, on personality traits and individual needs, such as this paper has investigated (Krosnick, 2018; Porst, 2014). Personality traits, if more extensively queried, can provide much deeper insights into the human psyche. However, in view of the length of the questionnaire, to go into more detail in this point would not fit our current goal.

To sum up, the presented questionnaire provides a solid basis for categorizing commuter types and can also be used in other research areas dealing with successful long-term IS adoption. On the basis of our findings, we will develop a revised version of the questionnaire, also taking into account developments in the field of (smart) mobility under the SARS-CoV-2 (Covid-19) pandemic (Bonaccorsi et al. 2020; Eckert & Mikosch, 2020; Kellerman, 2020), and conduct an additional survey. The results of this study will then form the basis for a comprehensive design theory to support developing an SMS that fosters long-term use of persuasive elements (Gregor & Jones, 2007; Anschütz et al. 2021).
References


